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ORIGINAL ARTICLE

Effect of surface treatment on wear behavior of magnesium alloy AZ31

Y. Fouad [a,*], M. El Batanouny [b]

[a] *Department of Materials Engineering, German University in Cairo–GUC, New Cairo City, Main Entrance Al Tagamoa Al Khames, Egypt*
[b] *Department of Design and Production Engineering, German University, Cairo, Egypt*

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KEYWORDS

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Abstract In the present study, wear test has been performed on wrought magnesium alloy AZ31 samples. The test samples were in different conditions as; in the as cast alloy or after undergoing different surface treatment of the wrought alloy. The surface treatments included ball burnishing, swaging and shot peening. The shot peening is done at two main pressure loads; 0.1 and 0.3 bars, while other parameters are held constant. The test results show that the wear worst results were observed in the as cast sample at pressure load 0.3 bars, while the shot peening sample has the worst wear rate among all samples at pressure load of 0.1 bars. On the other hand, the hardness test showed that the swaged sample has the highest hardness value among all samples.

1. Introduction

Magnesium alloys are the lightest metals being used in engineering applications. They offer a possible alternative to steel and aluminum in automotive and aero industries to satisfy the lightweight requirement. Presently, cast products take a predominant position in the magnesium applications due to their high productivity, good surface quality and acceptable dimensional precision [1]. However, structural components made from wrought alloys through metal forming processes have great advantages in strength and ductility over castings. One of the barriers to the applications of wrought magnesium alloys is their low workability, as a result of the hexagonal crystal structure. It has been demonstrated that the ductility enhancement in magnesium could be achieved by refining its grain structure [2,3].

* Corresponding author. Tel.: +27589990-8x1188; fax: +27581041; mobile: 0127995802.
E-mail address: yasser.fouad@guc.edu.eg (Y. Fouad).
URL: http://www.guc.edu.eg (Y. Fouad).

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Table 1 Chemical composition and mechanical properties of investigated alloy (wt%)

Al%	Ca%	Cu%	Fe%	Mn%	Ni%	Pb%	Si%	Sn%	Zn%	Zr%	Mg%
3.078	0.0573	0.0065	0.0054	0.3647	0.002	0.0075	0.0204	< 0.002	1.337	< 0.01	95.1
Material	Yield strength (MPa)		Tensile strength (MPa)		Elongation (%)		Young's modulus (GPa)				
AZ31	154.8		232		23.67		45				

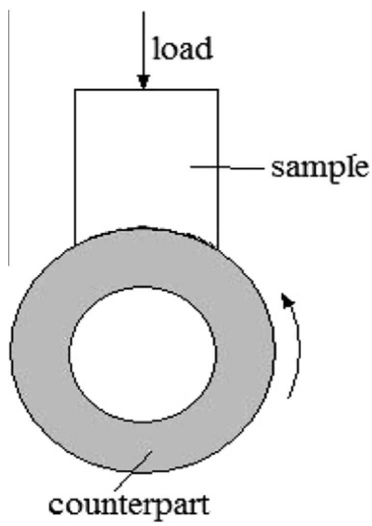

Figure 1 Illustration of wear test equipment.

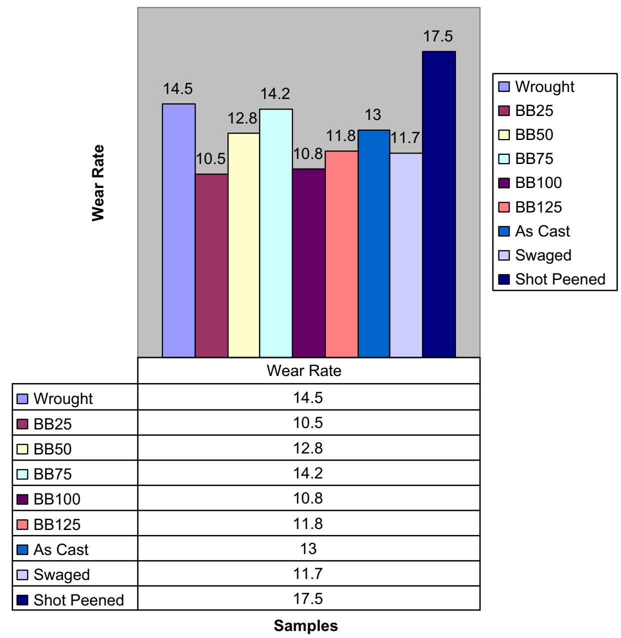

Figure 2 Wear rate (g/s $\times 10^6$) at 0.1 bars.

In the investigated alloy the base materials was magnesium with addition of Al, Zn and Mn. The processes used in surface treatment of AZ31 magnesium alloy are; either cold as ball burnishing and shot peening or hot as in swaging [4,5]. Ball burnishing is a method of cold work deformation and burnishing where compressive residual stresses are introduced below the surface. Swaging is a hot working process where large pieces of metal are heated above their recrystallization temperature and then deformed between swaggers to form thinner cross sections [6–8]. Hot working will reduce the average grain size of a metal while maintaining an equiaxed microstructure whereas cold working produces a hardened microstructure [9]. The shot peening is a process used to produce a compressive residual stress layer and to modify mechanical properties of metals. It entails impacting a surface with shot round metallic, glass or ceramic particles with force sufficient to create plastic deformation. It is similar to sandblasting, except that it operates by the mechanism of plasticity rather than abrasion: each particle functions as a ball-peen hammer [10,11]. In practice, this means that less material is removed by the process, and less dust created.

Casting is a manufacturing process by which the metal is melted and poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is ejected or broken out of the mold to complete the process [12].

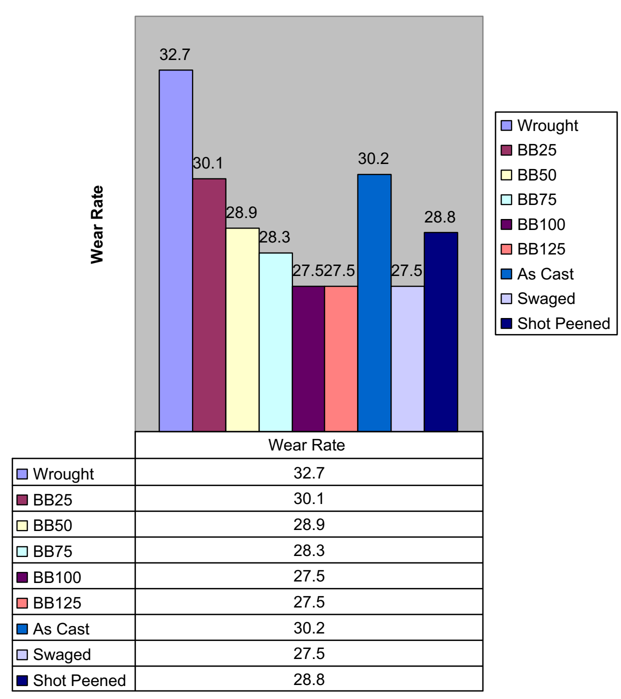

Figure 3 Wear rate (g/s $\times 10^6$) at 0.3 bars.

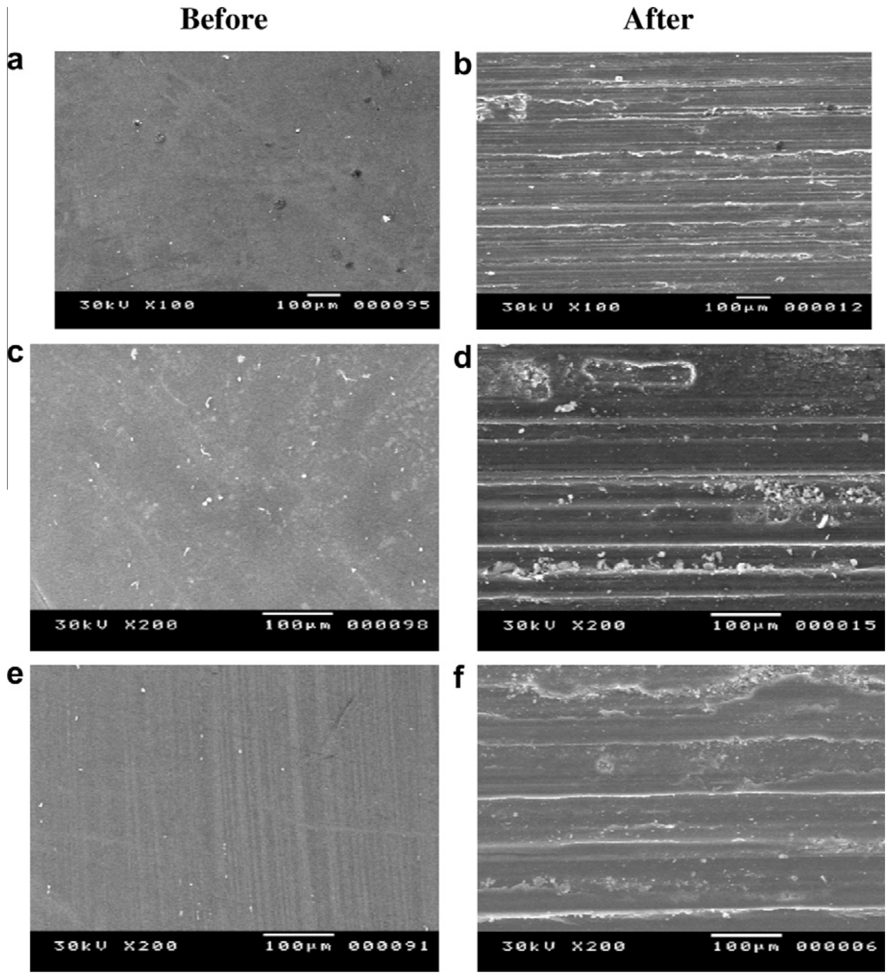

Fig. 4 SEM of as cast sample (a) before wear test (b) after wear test, for BB75 (c) before wear test (d) after wear test, for Swaged sample (e) before wear test (f) after wear test.

Table 2 Hardness values for investigated alloys (HV).

Sample	Hardness (HV)
Wrought	54.2
BB25	47.2
BB50	60.5
BB75	53
BB100	51.8
BB125	50.9
As cast	58.7
Swaged	93.8
Shot peened	58.5

2. Experimental procedure

2.1. Magnesium alloy and test sample preparation

AZ31 is a wrought magnesium alloy that is mainly alloyed with aluminum and zinc. Table 1 shows the chemical composition and the mechanical properties of the AZ31 magnesium alloy employed in this study. Tensile tests were performed using specimens with a gauge length of 14 mm and a gauge diameter of 5 mm.

A group of eight samples, as shown in Fig. 1, were tested. The BB samples are those samples prepared using the ball burnishing technique. The BB samples are prepared on the ECO-ROLL machine using tool type (HG6) at 40 bars with feed rate at 0.15 mm/min and at 150 rpm. The BB samples pressures are; at 25, 50, 75, 100 and at 125 bars. The hardness test was measured by using Vickers hardness Zwick/Roell ZHV machine.

2.2. Mechanical wear test procedure

The device used in this test is called the Mechanical Wear Testing Machine. The mechanical wear test is carried out in order to estimate the ability of the metal to resist the wear phenomena .The samples are tested as follows;

- The rod sample is fixed in a chuck and pushed, with a certain loading, in a normal direction against a rotating disk.
- When the disk starts to rotate, the contact surface of the rod is being rubbed against the disk.
- The test duration is 30 min.

The speed of the rotation and the value of the load determine the wear rate of the material. The wear rate is determined by weighing the rod before and after. The main parameters of the mechanical wear test are the disk's speed of rotation, the load applied through on the rod samples and the test time. In this study, the speed is 150 rpm, the pressure loads are of 0.1 and 0.3 bars and the test time is taken as 30 min.

3.1. Metallography

The microscope used in this regard is the JEOL 5410 Scanning Electron Microscope at 20.9 °C and 35% humidity. SEM images are taken for three samples which are the BB 75, the swaging sample, and the as cast sample. Each sample was scanned before and after wear to monitor the change occurring on the test surface.

4. Results and discussion

4.1. Wear behavior

The results shown in Fig. 2 were revealed at test conditions of; 0.1 bars applied load, 150 rpm speed of rotation and 30 min of test time.

These results showed that wear rates values are more or less the same in all the surface treated samples except for the shot peened sample which showed the highest wear rate.

A second wear test is then performed yet at different test parameters. The load pressure of the wear machine has been increased to 0.3 bars, while the rpm and the test time are the same. The second test results are summarized in Fig. 3. It is obvious that the wear rates of the 8 samples are close to each other and this is due to the similarity in the way they were surface treated. And since the samples are almost identical in size, the differences between the readings are slight. It can also be noted that the ball burnishing samples BB100 and BB125 gave the same result as the swaging sample.

4.2. Scanning Electron Microscope (SEM)

SEM photos for the surface treated samples before and after wear test done at pressure load of = 0.3 bars, speed of 150 rpm and time of = 30 min are shown in Fig. 4.

The worn surface morphological features of AZ31 were illustrated at different surface treatments as in Fig. 3. It could be observed that the worst wear rate appeared in the BB75 sample, Fig. 3d next is the wear that resulted from the swaging and the least wear effect is in the as cast sample.

Table 2 shows the hardness results on the test samples. The swaged samples gave the highest hardness while all the other samples produced more or less a close hardness value.

5. Conclusion

The study came with the following conclusions:

(1) The wear rate value of all AZ31 test samples did not differ under different surface treatment situations when the applied pressure was low.
(2) At higher pressure loads, the wear rate value decreased as compared to the wrought alloy AZ31.
(3) The shot peening sample has the greatest wear rate among all samples at a pressure load of 0.1 bars.
(4) The hardness of the samples depends mainly on the nature of the surface treatment process; hence, the swaged sample gave the highest value of hardness followed by the ball burnished samples.

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